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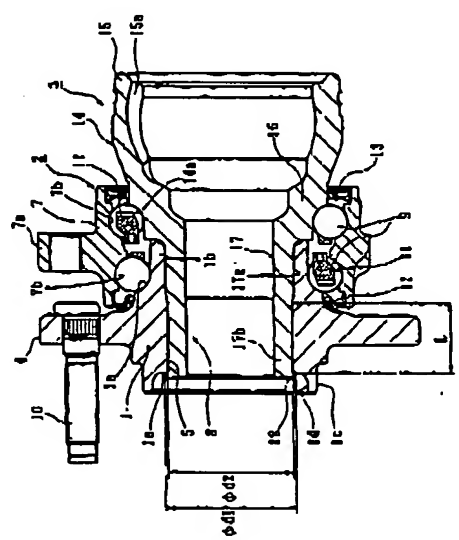
(54) **Bearing apparatus for a wheel of a vehicle**

(57) A bearing apparatus for a driving wheel of vehicle wherein the hub wheel 1, the constant velocity universal joint 3 and the double row rolling bearing 2 are assembled as a unit, the hub wheel 1 and the outer joint member 14 of the constant velocity universal joint 3 are fitted each other; at least one of the inner raceway surface 1a of the double row rolling bearing 2 is formed on the hub wheel; a hardened irregular portion 5 is formed on the inner circumferential surface of the hub wheel 1; the hub wheel 1 and the outer joint member 14 are integrally connected via plastic deformation of a fitting portion 17b of the outer joint member so as to make the hardened irregular portion 5 to bite into the surface of the fitting 17b; and a connected portion of them has a plastic deformed connection means having an axial pull-out proof force more than 160 kN.

Fig. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a bearing apparatus for supporting a driving wheel of vehicle and more particularly to a bearing apparatus for a wheel of vehicle in which a hub wheel, a constant velocity universal joint and a double row rolling bearing are assembled as a unit.

Description of Background Art

[0002] The driving wheels such as rear wheels of an FR (Front engine/Rear drive) vehicle, front wheels of an FF (Front engine/Front drive) vehicle and all wheels of a 4WD (4-wheel Drive) vehicle are supported by a suspension system via a bearing apparatus for a wheel. In recent years, it has a tendency to assemble the hub wheel, the constant velocity universal joint and the double row rolling bearing as a unit in order to reduce the weight and the size of the bearing apparatus for a wheel.

[0003] Fig. 14 is a longitudinal cross-section view of a bearing apparatus for a driving wheel of vehicle of the prior art in which a hub wheel 50, a double row rolling bearing 60 and a constant velocity universal joint 70 are assembled as a unit. The hub wheel 50 is formed integrally with a wheel mounting flange 51 for mounting a wheel (not shown) thereon and hub bolts 52 for securing the wheel are equidistantly arranged along the periphery of the flange 51.

[0004] The double row rolling bearing 60 comprises an outer member 61, an inner member 62 and double row rolling elements 63 and 63 and the outer member 61 has a flange 64 integrally formed therewith to be mounted on a body of vehicle (not shown) and double row outer raceway surfaces 61a and 61a formed on the inner surface thereof. In this case, the inner member 62 comprises the hub wheel 50 and an outer joint member 71. The inner member 62 is formed with double row inner raceway surfaces 50a and 71a arranged respectively opposite to the outer raceway surfaces 61a and 61a of the outer member 61. The inner raceway surface 50a is formed on the outer circumferential surface of the hub wheel 50 and the other raceway surface 71a is formed on the outer circumferential surface of the outer joint member 71 of the constant velocity universal joint 70. The double row rolling elements 63 and 63 are arranged between the outer raceway surfaces 61a and 61a and the inner raceway surfaces 50a and 71a and rotatably held therein by cages 65 and 65. Seals 66 and 67 are arranged at the ends of the double row rolling bearing 60 in order to prevent leak of grease contained within the bearing and also to prevent incoming of rain water or dusts.

[0005] The constant velocity universal joint 70 comprises the outer joint member 71, a joint inner ring, a cage and a torque transmission balls (not shown). The outer joint member 71 has a cup shaped mouth portion 72, a shaft portion 73 axially extending from the mouth portion 72, and axially extending curved track grooves 72a formed on the inner surface of the mouth portion 72.

[0006] The hub wheel 50 is formed with hardened irregular portion 53 on the inner circumferential surface thereof. The hub wheel 50 and the outer joint member 71 are mutually connected by fitting the shaft portion 73 of the outer joint member 71 into the hub wheel 50 and then by radially outwardly expanding the fitting portion of the outer joint member 71 so that causing plastic deformation of the outer joint member 71 with making the hardened irregular portion 53 to bite into the outer circumferential surface at the fitting portion of the outer joint member71 (see pages 4 and 5 and Fig. 1 of Japanese Laid-Open Patent Publication No. 18605/2001).

[0007] Such a structure of connection via the plastic deformation can prevent loosening and abrasion of the fitted portion and thus can improve the durabilty and the driving stability. In addition, since the connection via the plastic deformation has both functions of torque transmission and connection of the hub wheel and the outer joint member, it is possible to achieve reduction of the weight and size of the apparatus.

[0008] In such a bearing apparatus for a wheel, it is difficult to confirm the state of connection between the hub wheel 50 and the outer joint member 71 since the connection via plastic deformation is adopted therebetween, and thus, the confirmation of the strength and endurance of the connected portion is carried out by the breakdown test via sampling inspection. It is desired to further improve the quality and reliability of the connected portion since the defect of the quality will cause falling out of wheel which would cause a dangerous accident.

[0009] For solving this problem, the applicant has proposed a bearing apparatus for a wheel of vehicle shown in Fig. 13. In this bearing apparatus a hardened irregular portion 53 is formed on a radially outwardly arranged member (in this case the hub wheel 50') at the fitted portion of the hub wheel 50' and the outer joint member 71'; and the hub wheel 50' and the outer joint member 71' are integrally connected via plastic deformation of a radially inwardly arranged member (in this case the outer joint member 71') by radially outwardly expanding the radially inwardly arranged member so as to make the hardened irregular portion of the radially outwardly arranged member to bite into the surface of the radially inwardly arranged member and are axially secured via a caulked portion 74 formed by plastically deforming the end of the radially inwardly arranged member 71' (see pages 3 and 4, Fig. 1 and Fig.2 of Japanese Laid-Open Patent Publication No. 89301/2003).

SUMMARY OF THE INVENTION

[0010] However, such a bearing apparatus requires

the caulking step or a retaining ring mount step in addition to the connecting step of the hub wheel 50' and the outer joint member 71' via plastic deformation therebetween. In recent years, not only compactness and light weight of the bearing apparatus but improvement of quality and reliability thereof as well as low manufacturing cost are required in the art.

[0011] It is, therefore, an object of the present invention to provide a bearing apparatus for a driving wheel of vehicle of low manufacturing cost in which no loose is caused in the connected portion even if heavy moment is applied thereto and no pre-press pull-out is caused.

[0012] For achieving the object above, there is provided, according to the present invention of claim 1, a bearing apparatus for a wheel of vehicle wherein a hub wheel, a constant velocity universal joint and a double row rolling bearing are assembled as a unit: the hub wheel and an outer joint member of a constant velocity universal joint are fitted each other; and a connected portion of the hub wheel and the outer joint member has a plastic deformed connection means having an axial pull-out proof force more than 160 kN.

[0013] According to the bearing apparatus of claim 1, it is possible to provide a bearing apparatus for a wheel of vehicle of low manufacturing cost in which no loose is caused in the connected portion and durability can be maintained for a long term.

[0014] According to the invention of claim 2, there is provided a bearing apparatus for a driving wheel of vehicle comprising an outer member formed with double row outer raceway surfaces on the inner peripheral surface thereof and double row inner raceway surfaces arranged oppositely to the double row outer raceway surfaces wherein an inner ring on the outer peripheral surface of which is formed with one of double row inner raceway surfaces is fitted into a hub wheel integrally formed with a wheel mounting flange or into another inner ring on the outer peripheral surface of which is formed with the other double row inner raceway surfaces; and a connected portion of them has a plastic deformed connection means having an axial pull-out proof force more than 160 kN.

[0015] According to the bearing apparatus of claim 2, it is possible to provide a bearing apparatus for a wheel of vehicle of low manufacturing cost in which no loose is caused in the connected portion, any gap variation of the double row rolling bearing is not caused even if a predetermined moment load is applied thereto and thus and durability can be maintained for a long term.

[0016] According to the invention of claim 3, there is provided a bearing apparatus for a driving wheel of vehicle wherein the hub wheel, the constant velocity universal joint and the double row rolling bearing are assembled as a unit, the hub wheel and the outer joint member of the constant velocity universal joint are fitted each other; one of the inner raceway surfaces of the double row rolling bearing is formed on the hub wheel and the other of the double row inner raceway surfaces is formed on the outer joint member; a hardened irregular portion is formed on a radially outwardly arranged member at the fitted portion of the hub wheel and the outer joint member; and the hub wheel and the outer joint member are integrally connected via plastic deformation of a radially inwardly arranged member by radially outwardly expanding the radially inwardly arranged member so as to make the hardened irregular portion of the radially outwardly arranged member to bite into the surface of the radially inwardly arranged member. The connected portion according to this structure has a sufficient axial pull-out proof force and can achieve the bearing apparatus of light weight and compact as well as low manufacturing cost.

[0017] According to the bearing apparatus of claims 4 or 5 having the structure of so-called a fourth generation, it is possible to reduce the number of parts, to prevent the loose of the connected portion even if the repeated stress would be caused due to application of the bending moment to the bearing apparatus when a vehicle is turned, and further to increase the pulling-out proof force.

[0018] According to the bearing apparatus of claim 6 having the structure of so-called a third generation, it is possible to provide a self-retaining structure enabling to keep the initial bearing gap and to lower the manufacturing cost due to standardization of the bearing parts.

[0019] According to the bearing apparatus of claim 7, the portion to be radially outwardly expanded is projected beyond the hardened irregular portion. This structure enables to increase the pull-out proof force at the connected portion in addition to increase of the pull-out proof force at the plastically deformed connected portion.

[0020] According to the bearing apparatus of claim 8, it is possible to effectively assure the pull-out proof force by the annular grooves and the torque transmission by the axial grooves and to increase the pull-out proof force at the connected portion by the projected and enlarged portion.

[0021] According to the bearing apparatus of claim 9, it is possible to maintain the initial bearing gap and to assure a desired endurance for a long term.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Additional advantages and features of the present invention will become apparent from the subsequent description and the appended claims, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a longitudinal section view showing a first embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 2 (a) is a longitudinal section view showing a crisscross pattern knurl formed by mutually crossed axial grooves and discontinuous annular grooves

as an irregular portion, and Fig. 2 (b) is a longitudinal section view showing a crisscross pattern knurl formed by mutually inclined helical grooves as an irregular portion;

Fig. 3 (a) is a partially enlarged section view of the first embodiment of the bearing apparatus for a wheel of the present invention, and Fig.3 (b) is a partially enlarged side elevation view of Fig. 3 (a);

Fig. 4 is a longitudinal section view showing a second embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 5 is a longitudinal section view showing a third embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 6 is a longitudinal section view showing a fourth embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 7 is a longitudinal section view showing a fifth embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 8 is a longitudinal section view showing a sixth embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 9 is a longitudinal section view showing a seventh embodiment of the bearing apparatus for a wheel of the present invention which is a modification of the sixth embodiment;

Fig. 10 is a longitudinal section view showing an eighth embodiment of the bearing apparatus for a wheel of the present invention;

Fig. 11 is a longitudinal section view showing a ninth embodiment of the bearing apparatus for a wheel of the present invention which is a modification of the eighth embodiment;

Fig. 12 is a graph showing results of the pull-out test at the connected portion of the hub wheel and the outer joint member;

Fig. 13 is a longitudinal section view of the bearing apparatus for a wheel of the prior art; and

Fig. 14 is a longitudinal section view of another bearing apparatus for a wheel of the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Fig. 1 shows a first embodiment of a bearing apparatus for a driving wheel of vehicle of the present invention. The apparatus comprises a hub wheel 1, a double row rolling bearing 2 and a constant velocity universal joint 3 which are assembled as a unit. In the description below, a term "outboard side" of the apparatus denotes a side which is positioned outside of the vehicle body and a term "inboard side" of the apparatus denotes a side which is positioned inside of the body when the apparatus is mounted on the vehicle body.

[0024] The hub wheel 1 is formed integrally with a wheel mounting flange 4 at the outboard side of the hub wheel 1 on which a wheel (not shown) is mounted and hub bolts 10 are equidistantly arranged on the flange 4 along its periphery. The inner circumferential surface of the hub wheel 1 is formed with a irregular portion 5 which are heat treated as having a hardened layer having a surface hardness of HRC 54~64. It is preferable to use as heat treatment a high frequency induction heating which can easily carry out a local heating and a setting of the depth of a hardened layer.

[0025] Fig. 2 shows example of the irregular portion 5 in which Fig 2 (a) shows an example of the irregular portion 5 of substantially orthogonally crossed grooves 6 comprising a plurality of discontinuous lathe turned annular grooves 6a and a plurality of broached axial grooves 6b and Fig.2 (b) shows an example of the irregular portion 5 comprising mutually inclined helical grooves 6' of crisscross pattern. It is preferable to form the irregular portion 5 by pointed projections such as pyramids to assure a good biting performance.

[0026] The double row rolling bearing 2 comprises an outer member 7, inner member 8 and a double row rolling elements 9 and 9. The outer member 7 is integrally formed on its outer circumferential surface with a body mounting flange 7a and on its inner circumferential surface with double row outer raceway surfaces 7b and 7b. On the other hand, the inner member 8 comprises the hub wheel 1 and an outer joint member 14 hereinafter described and inner raceway surfaces 1a and 14a opposed to the outer raceway surfaces 7b and 7b are arranged on the outer circumferential surfaces of the hub wheel 1 and the outer joint member 14 respectively. The double row rolling elements 9 and 9 are contained between the outer raceway surfaces 7 b and 7b and the inner raceway surfaces 1a and 14a and freely rotatably held therein by cages 11 and 11. Seals 12 and 13 are arranged at the ends of the bearing 2 to prevent leak of grease contained within the bearing 2 as well as ingress of rain water or dusts. A hardened layer is formed for example by induction hardening at regions around the outer circumferential surface of the hub wheel 1 such as a seal land portion to which the seal 12 slidably contacts, the inner raceway surface 1a, and a surface of spigot portion 1b to which the shoulder 16 of the outer joint member 14 abuts. The illustrated ball rolling elements 9 and 9 may be replaced for example by conical rolling elements.

[0027] In such a kind of bearing apparatus, a larger moment is applied to the rolling bearing of the inboard side of the double row rolling bearing than that of the outboard side. According to the preferable embodiment of the present invention, the pitch circle diameter (PCD) of the rolling elements 9 of the inboard side is set somewhat larger than that of the rolling elements 9 of the outboard side in order to increase the load supporting capacity of the rolling bearing of the inboard side. It is also possible to increase the load supporting capacity by changing the number or size of the rolling elements 9 of the inboard side.

[0028] The constant velocity universal joint 3 compris-

es the outer joint member 14, the joint inner ring (not shown), the cage, and the torque transmitting balls. The outer joint member 14 comprises a cup-shaped mouth portion 15, a shoulder 16 forming the bottom of the mouth portion 15, a shaft portion 17 axially extending from the shoulder 16, and an axially extending curved track groove 15a formed on the inner surface of the mouth portion.

[0029] The inner raceway surface 14a is formed around the outer circumferential surface of the shoulder 16 of the hollow outer joint member 14. The shaft portion 17 has a stepped portion of small diameter 17a onto which the spigot portion 1b of the hub wheel 1 is press fitted and a fitting portion 17b onto which the hub wheel 1 is fitted. The fitting portion 17b is fitted into the hub wheel 1 with the end surface of the spigot portion 1b of the hub wheel 1 being abutted against the shoulder 16 of the outer joint member 14. Then the hub wheel 1 and the outer joint member 14 are integrally connected via plastic deformation of the fitting portion 17b of the outer joint member 14 with making the hardened irregular portion 5 of the hub wheel 1 to bite into the outer circumferential surface at the fitting portion of the outer joint member 14 by radially outwardly expanding the fitting portion of the outer joint member 14. Since the fitted portion via plastic deformation has both a torque transmitting function and a jointing function of the hub wheel 1 and the outer joint member 14, any provision of torque transmitting means such as a conventional serration means on the hub wheel 1 and the outer joint member 14 as well as axially securing means is not required and accordingly it is possible to realize further reduction of the weight and size of the apparatus.

[0030] The outer joint member 14 is formed with a hardened layer at the track groove 15a formed on the inner surface of the mouth portion 15, and a region from the seal land portion on which the seal slidably contacts to the stepped portion of small diameter 17a of the shaft portion 17 through the inner raceway surface 14a. It is preferable to carry out the heat treatment by the high frequency induction heating. It is also preferable to keep the fitting portion 17b as no-quenched portion having surface hardness less than HRC 24 and to set the surface hardness of the irregular portion 5 of the hub wheel 1 at about HRC 54~64 to hold a difference in the hardness between the irregular portion 5 and the fitting portion 17b larger than HRC 30. This enable the irregular portion 5 to easily bite into the fitting portion 17b without causing deformation of the irregular portion 5 to tightly combine them via the plastic deformation. Although not illustrated, an end cap is usually arranged at an end of the outer joint member 14 in order to prevent leakage of grease contained within the mouth portion 15 and ingress of dusts from the outside.

[0031] The region in which the irregular portion 5 is formed is set at an area from the wheel pilot portion 1c to a position near a line of action (i.e. an extension of a line connecting a contact point between the rolling element 9 and the inner raceway surface and the center of the rolling element 9). As shown in Fig. 3 (a), a counterbore 1d is formed on the radially inner surface of the pilot portion 1c so that the fitting portion 17b is projected from the outer end surface 1e of the hub wheel 1. This is intended to be formed a radially expanded end portion 18 after expanding of the fitting portion 17b. The outer diameter ϕ d1 of the radially expanded end portion 18 is larger than the bottom diameter ϕ d2 of the annular grooves 6a or the bottom diameter ϕ d3 of the axial grooves 6b of the irregular portion 5. Thus the radially expanded portion 18 can increase the axial pull-out proof force at the connected portion between the hub wheel 1 and the outer joint member 14. It is preferable to set the outer diameter ϕ d1 1.01~1.15 times the bottom diameters ϕ d2 and ϕ d3 of the annular grooves 6a and the axial grooves 6b respectively.

[0032] Fig. 4 is a longitudinal view showing a second embodiment of the bearing apparatus for a wheel of the present invention. This embodiment differs from the first embodiment only in that the counterbore is not formed in the pilot portion of the hub wheel and thus same reference numerals are used for designating same parts.

[0033] In the bearing apparatus of this embodiment, a hub wheel 1', the double row rolling bearing 2 and the constant velocity universal joint 3 are assembled as a unit. The wheel pilot portion 1c of the hub wheel 1' is not formed with any counterbore and thus the radially inner surface of the pilot portion 1c is extended longer than that in the first embodiment. Accordingly the length of the fitting portion 17b' of the shaft portion 17 of the outer joint member 14 is also extended. The outer end 18 of the fitting portion 17b' is positioned slightly beyond the outer end surface 1e of the hub wheel 1'. In this embodiment, the length L' of caulking portion of the fitting portion 17b' is longer than that L in the first embodiment (L'<L) and thus higher pull-out proof force can be obtained as compared with the first embodiment.

[0034] Fig. 5 is a longitudinal view showing a third embodiment of the bearing apparatus for a wheel of the present invention. This embodiment differs from the aforementioned embodiments only in the structure of the connected portion between the hub wheel and the outer joint member and thus same reference numerals are used for designating same parts.

[0035] The radially inner surface of the hub wheel 1 is formed with the hardened irregular portion 5'. The hub wheel 1 and the outer joint member 14 are integrally connected via plastic deformation by making the hardened irregular portion 5' of the hub wheel 1 to bite into the fitting portion 17b" of the shaft portion 17 the outer joint member 14. The region in which the irregular portion 5' is formed is set at an area from the wheel pilot portion 1c to a position near a line of action of the rolling element 9. The counterbore 1d is formed on the end surface of the outboard side of the hub wheel 1.

[0036] The length of the fitting portion 17b" is determined so that the end surface of the fitting portion 17b"

substantially corresponds to the outer end surface 1e of the hub wheel 1. As to the irregular portion 5', substantially orthogonally crossed grooves 6 are formed by a plurality of discontinuous lathe turned annular grooves 6a and a plurality of broached axial grooves (not shown). The depths of the annular grooves and the axial grooves are substantially same. The number, size are appropriately determined so as to enable the hardened projections (each having a pyramid configuration) of the irregular portion 5' to bite into the fitting portion 17b". In addition, the radially inner diameter of the irregular portions 5' of the hub wheel 1, the radially inner diameter of the fitting portion 17b" and the radially outer diameter of the expanding tool such as a mandrel are determined so that the irregular portion 5' can effectively bite into the material of the fitting portion 17".

[0037] Fig. 6 is a longitudinal view showing a fourth embodiment of the bearing apparatus for a wheel of the present invention. In the bearing apparatus of this embodiment, a hub wheel 19, a double row rolling bearing 2' and a constant velocity universal joint 21 are assembled as a unit. Same reference numerals are used for designating same parts.

[0038] The hub wheel 19 is formed integrally with a wheel mounting flange 4 for mounting a wheel (not shown) thereon and hub bolts 10 for securing the wheel are equidistantly arranged along the periphery of the flange 4. The inner raceway surface 1a of the outboard side is formed on the outer circumferential surface of the hub wheel 1 and the stepped portion of smaller diameter 19a and the fitting portion 19b are extended from the inner raceway surface 1a.

[0039] The double row rolling bearing 2' comprises an outer member 7, an inner member 8' and double row rolling elements 9 and 9. The outer member 7 has a flange 7a integrally formed therewith to be mounted on a body of vehicle (not shown) and double row outer raceway surfaces 7b and 7b formed on the inner surface thereof. In this case, the inner member 8' comprises the hub wheel 19 and an outer joint member 20. The inner raceway surface 1a of outboard side and the inner raceway surface 20a of the inboard side respectively corresponding to the outer raceway surfaces 7b and 7b of the outer member 7 are formed on the outer circumferential surfaces of the hub wheel 1 and the outer joint member 20 respectively. The double row rolling elements 9 and 9 are arranged between the outer raceway surfaces 7b and 7b and the inner raceway surfaces 1a and 20a and rotatably held therein by cages 11 and 11. Seals 12 and 13 are arranged at the ends of the double row rolling bearing 2' in order to prevent leak of grease contained within the bearing and also to prevent incoming of rain water or dusts.

[0040] The hub wheel 19 is formed with a hardened layer at the seal land portion on which the seal lip of the seal 12 slides, the inner raceway surface 1a and the stepped portion of small diameter 19a which are heat treated by the high frequency induction heating. The fitting portion 19b to be radially enlarged is remained as no heat treated portion having a surface hardness less than HRC 24 after forging.

[0041] The outer joint member 20 of the constant velocity universal joint 21 is made of medium carbon steel such as S53C and has the cup-shaped mouth portion 15 and the shoulder 22 forming the bottom of the mouth portion 15. The inner raceway surface 20a of the inboard side is directly formed on the outer circumferential surface of the hollow shoulder portion 22. An irregular portion 23 is formed on the inner circumferential surface of the shoulder 22 and is heat treated as having a surface hardness of HRC 54~64. It is preferable to use the high frequency induction heating which can easily carry out the setting of the depth of hardened layer. It is also possible to have a hardened layer throughout the surface thereof by carburized hardening case-hardened steel such as SCr420.

[0042] The shoulder 22 of the outer joint member 20 is fitted onto the fitting portion 19b of the hub wheel 19 with the shoulder 22 press fitted onto the stepped portion of smaller diameter 19a of the hub wheel 19 being abutted against the hub wheel 19. Then the hub wheel 19 and the outer joint member 20 are integrally connected via plastic deformation of the fitting portion 19b with making the hardened irregular portion 23 of the shoulder 22 to bite into the outer circumferential surface of the fitting portion 19b. Similarly to the first and second embodiments, since the projected end 24 can be radially outwardly expanded without any constraint to its diameter exceeding the bottom diameter of the axial grooves or annular grooves forming the irregular portion 23, it is possible to increase the pull-out proof force at the connected portion between the hub wheel 19 and the outer joint member 20.

[0043] Fig. 7 is a longitudinal view showing a fifth embodiment of the bearing apparatus for a wheel of the present invention. In the bearing apparatus of this embodiment, a hub wheel 25, a double row rolling bearing 26 and a constant velocity universal joint 27 are assembled as a unit. Same reference numerals are used for designating same parts.

[0044] The hub wheel 25 is formed integrally with a wheel mounting flange 4 at the outboard side of the hub wheel 1 on which a wheel (not shown) is mounted. The inner raceway surface 25a of the outboard side is formed on the outer circumferential surface of the hub wheel 25 and the spigot portion 25b is extended from the inner raceway surface 25a. A separate inner ring 29 is press fitted onto the spigot portion 25b to form a bearing apparatus of so-called a third generation. A serration (or spline) 28 is formed on the inner circumferential surface of the hub wheel 25 and an annular engaging groove 28a is formed at the end thereof. The hub wheel 25 is formed with a hardened layer at the seal land portion on which the seal lip of the seal 12 slides, the inner raceway surface 25a and the spigot portion 25b which are heat treated by the high frequency induction heating.

The fitting portion 19b to be radially enlarged is remained as no heat treated portion having a surface hardness less than HRC 24 after forging.

[0045] The inner ring 29 is formed with the inner raceway surface 29a of the inboard side on the outer circumferential surface thereof and the irregular portion 30 on the inner circumferential surface thereof. The inner ring 29 is made of high carbon chrome bearing steel and is hardened to its core by dipping quenching to have the surface hardness at least of HRC 58~64. The hub wheel 25 and the inner ring 29 are integrally connected via plastic deformation by radially expanding the spigot portion 25b of the hub wheel 25 to make the hardened irregular portion 30 bite into the spigot portion. When the spigot portion 25b is axially projected beyond the irregular portion 30, the radially expanded end 25c can engage a chamfered portion 29b of the inner ring 29. Thus, it is possible to increase the pull-out proof force at the connected portion between the hub wheel 25 and the inner ring 29.

[0046] The outer joint member 31 of the constant velocity universal joint 27 is made of medium carbon steel such as S53C and has the cup-shaped mouth portion 15, the shoulder 32 forming the bottom of the mouth portion 15, and the shaft portion 33 axially extending from the shoulder portion 32. The shaft portion 33 is formed with a stepped portion of smaller diameter 33a and a serration (or spline) 34 engaging the serration 28 of the hub wheel 25. A groove 34a formed on the forward end of the serration 34 receives therein a clip 35 having a round cross section. The portion from the shoulder 32 to the stepped portion 33a is is hardened to have the surface hardness at least of HRC 54~64.

[0047] The shaft portion 33 is fitted into the hub wheel 25 with keeping the clip 35 mounted within the groove 34a of the serration 34 in its compressed condition until the end surface of the inner ring 29 abuts against the shoulder 32 of the outer joint member 31. When the clip 35 arrives at the groove 28a formed on the serration 28 of the hub wheel 25, the clip 35 springs back into the groove 28a. The hub wheel 25 and the outer joint member 31 can be connected axially detachably each other by engaging or disengaging the clip 31 with the grooves 28a and 34a. In this embodiment, since the hub wheel 25 and the inner ring 29 are connected via the plastic deformation, it is possible to prevent the pull-out of the double row rolling bearing 26 even if a predetermined pulling-out force is applied thereto.

[0048] Fig. 8 is a longitudinal view showing a sixth embodiment of the bearing apparatus for a wheel of the present invention. In the bearing apparatus of this embodiment, a hub wheel 36, a double row rolling bearing 37 and a constant velocity universal joint (not shown) are assembled as a unit. Same reference numerals are used for designating same parts.

[0049] The hub wheel 36 is formed integrally with a wheel mounting flange 4 at the outboard side of the hub wheel 1 on which a wheel (not shown) is mounted. The spigot portion 36b is extended from the wheel mounting flange 4. The double row rolling bearing 37 is press fitted onto the spigot portion 36b and thus the bearing apparatus of so-called a first generation is provided. The serration (or spline) is formed on the inner circumferential surface of the hub wheel 36. The hub wheel 36 is made of medium carbon steel such as S53C and its outer circumferential surface in the base of inboard side of the wheel mounting flange 4 and the spigot portion 36b is heat treated by the high frequency induction heating. The fitting portion 36c at the end of the spigot portion 36b to be radially enlarged is remained as no heat treated portion having a surface hardness less than HRC 24 after forging.

[0050] The double row rolling bearing 37 comprises an outer ring 38 formed on its inner circumferential surface with a double row outer raceway surface 7b and a pair of inner rings 39 and 29. The inner ring 39 is formed on its outer circumferential surface with an inner raceway surface 39a of outboard side. The inner ring 29 is formed with an inner raceway surface 29a of inboard side on its outer circumferential surface and with an irregular portion 30 on its inner circumferential surface. These outer ring 38 and inner ring 39 and 29 is made of high carbon chrome bearing steel and is hardened to its core by dipping quenching to have the surface hardness at least of HRC 58~64. The hub wheel 36 and the inner ring 29 are integrally connected via plastic deformation by radially expanding the fitting portion 36c of the spigot portion 36b of the hub wheel 36 to make the hardened irregular portion 30 bite into the fitting portion 36c.

[0051] The serration 28 of the hub wheel 28and the region from the inner diameter to the end surface 36d (shown by a dotted line) are formed after the double row rolling bearing 37 has been integrally secured to the hub wheel 36. The inner ring 29 is axially detachably connected by using a nut or a clip to an outer joint member (not shown) with the end surface of the inner ring 29 being abutted to the shoulder of the outer joint member. In this embodiment, since the hub wheel 36 and the inner ring 29 are connected via the plastic deformation, it is possible to prevent the pull-out of the double row rolling bearing 37 even if a predetermined pulling-out force is applied thereto.

[0052] Fig. 9 is a longitudinal view showing a seventh embodiment of the bearing apparatus for a wheel of the present invention which is a modification of the sixth embodiment (Fig. 8). In this embodiment, a double row rolling bearing 40, a hub wheel (not shown), and a constant velocity universal joint (not shown) are assembled as a unit. Same reference numerals are used for designating same parts as those of the sixth embodiment.

[0053] The double row rolling bearing 40 comprises an outer ring 38 formed on its inner circumferential surface with a double row outer raceway surface 7b and a pair of inner rings 41 and 29. The inner ring 41 is formed on its outer circumferential surface with an inner raceway surface 41a of outboard side and a spigot portion

41b of smaller diameter extends from the inner raceway surface 41a. The inner ring 29 is press fitted onto the spigot portion 41b and thus the bearing apparatus of so-called a first generation is provided. The hub wheel 41 is made of medium carbon steel such as S53C and the inner raceway surface 41a and the spigot portion 41b are heat treated by the high frequency induction heating. The fitting portion 41c at the end of the spigot portion 41b to be radially enlarged is remained as no heat treated portion having a surface hardness less than HRC 24 after forging.

[0054] The inner wheel 41 and the inner ring 29 are integrally connected via plastic deformation by radially expanding the fitting portion 41c of the inner ring 41 to make the hardened irregular portion 30 of the inner ring 29 bite into the fitting portion 41c. Then the double row rolling bearing 40 is press fitted onto the hub wheel (not shown) after having finished by grinding a region from the inner circumferential surface of the inner ring to an end surface 41d (dotted line). Similarly to the six embodiment, The inner ring 29 is axially detachably connected by using a nut or a clip to an outer joint member with the end surface of the inner ring 29 being abutted to the shoulder of the outer joint member.

[0055] Fig. 10 is a longitudinal view showing a eighth embodiment of the bearing apparatus for a wheel of the present invention. In this embodiment, a hub wheel 36, a double row rolling bearing 42 and a constant velocity universal joint (not shown) are assembled as a unit. This embodiment differs from the sixth embodiment (Fig. 8) only in the structure of the double row rolling bearing and thus same reference numerals are used for designating same parts as those of the sixth embodiment.

[0056] The double row rolling bearing 42 has the outer member 7 formed integrally with a body mounting flange 7a and the double row outer raceway surface 7b on the inner circumferential surface, and a pair of inner rings 39 and 29. In this embodiment, the double row rolling bearing 42 is press fitted onto the spigot portion 36b of the hub wheel 36 and thus the bearing apparatus of so-called a second generation is provided. The hub wheel 41 and the inner ring 29 are integrally connected via plastic deformation by radially expanding the fitting portion 36c of the spigot portion 36b to make the hardened irregular portion 30 of the inner ring 29 bite into the fitting portion 36c.

[0057] Fig. 11 is a longitudinal view showing a ninth embodiment of the bearing apparatus for a wheel of the present invention which is a modification of the eighth embodiment (Fig. 10). In this embodiment, a double row rolling bearing 43, a hub wheel (not shown), and a constant velocity universal joint (not shown) are assembled as a unit. Same reference numerals are used for designating same parts as those of the eighth embodiment.

[0058] The double row rolling bearing 43 has the outer member 7 formed integrally with a body mounting flange 7a on the outer circumferential surface and the double row outer raceway surface 7b on the inner circumferential surface, and a pair of inner rings 41 and 29. The inner ring 41 is formed on its outer circumferential surface with an inner raceway surface 41a of outboard side and a spigot portion 41b of smaller diameter extends from the inner raceway surface 41a. The inner ring 29 is press fitted onto the spigot portion 41b and thus the bearing apparatus of so-called a first generation is provided. The hub wheel 41 and the inner ring 29 are integrally connected via plastic deformation by radially expanding the fitting portion 41c of the inner ring 41 to make the hardened irregular portion 30 of the inner ring 29 bite into the fitting portion 41c. Then the double row rolling bearing 40 is press fitted onto the hub wheel and similarly to the six embodiment, the hub wheel is axially detachably connected to the outer joint member by using a nut or a clip to an outer joint member. Similarly to the eighth and ninth embodiments as well as the sixth and seventh embodiments, Then the region from the inner circumferential surfaces of the hub wheel 36 and the inner ring 41 to an end surfaces 36d and 41d (dotted line) including the serration 28 is finished by grinding after having radially enlarged the fitting portion.

[0059] It is shown, according to the pull-out test of the connected portion carried out by the applicant, that the connecting manner of plastic deformation of the fitting portion of the shaft portion by the irregular portion of the hub wheel (hereinafter referred to "enlarged caulking") exhibits higher pull-out proof force than the conventional connecting manner of forming the caulked portion by radially outward plastic deformation of the end portion of the shaft of the outer joint member (hereinafter referred to "swing caulking"). In addition, According to the endurance test simultaneously carried out, it is shown that the reduction of the axial force is caused by generation of the reduction of the predetermined pre-press amount of the double row rolling bearing when the connecting force is low, if the predetermined moment load is applied to the bearing apparatus. The reduction of the axial force would cause the breakage of the connected portion. Accordingly, it is important to study the relation between the pull-out proof force of the connected portion and the durability of the bearing apparatus.

[0060] The applicant carried out the pull-out test of the connected portion based upon several samples made by the conventional swing caulking manner and the enlarged caulking manner. Fig. 12 shows the results of the pull-out test. It is found that there is a point (i.e. starting point of slippage of the connected portion) at which the displacement in the connected portion is suddenly caused during gradually increasing the pull-out load for axially separating the connected portion between the hub wheel and the outer joint member. That is, the slippage starting point induces the pre-press pull-out and thus causes the reduction of the axial force. It is furthermore found that the pull-out proof force gives dominant influence to the durability of the bearing apparatus.

[0061] In Fig. 12, Embodiments B and C denote the first embodiment (Fig. 1), Embodiment A denotes the

fourth embodiment (Fig. 6), Embodiment D denotes the second embodiment (Fig. 4), Embodiment E denotes the fifth embodiment (Fig. 7), and Embodiment F denotes the third embodiment (Fig. 5). On the other hand, Examples G, H, J and K denotes the results of tests as to the structures using conventional swing caulking manner.

[0062] As can be seen from these results, the enlarged caulking manner exhibits the pull-out proof force more than 2 times that according to the conventional swing caulking manner and a smaller displacement in the connected portion as well as higher rigidity as compared with the conventional structure. In the conventional swing caulking manner, although small displacement can be maintained below pull-out load of about 80 kN, the slippage is suddenly caused beyond this point and thus the generation of the pre-press pull-out of the bearing portion is supposed. On the contrary, according to the enlarged caulking manner, little displacement is caused in the connected portion below pull-out load of about 200kN and sufficient rigidity can be obtained. In addition, sufficient rigidity can be obtained and no slippage is caused beyond 160 kN even though the connected portion is made in accordance with the conventional enlarged caulking manner, by optimally setting the specifications of the annular and axial grooves forming the irregular portion.

[0063] The present invention has been described with reference to the preferred embodiments. Obviously, modifications and alternations will occur to those of ordinary skill in the art upon reading and understanding the preceding detailed description. It is intended that the present invention be construed as including all such alternations and modifications insofar as they come within the scope of the appended claims or the equivalents thereof.

Claims

1. A bearing apparatus for a driving wheel of vehicle wherein a hub wheel, a constant velocity universal joint and a double row rolling bearing are assembled as a unit: the hub wheel and an outer joint member of a constant velocity universal joint are fitted each other; and a connected portion of the hub wheel and the outer joint member has a plastic deformed connection means having an axial pull-out proof force more than 160 kN.

2. A bearing apparatus for a driving wheel of vehicle comprising an outer member formed with double row outer raceway surfaces on the inner peripheral surface thereof and double row inner raceway surfaces arranged oppositely to the double row outer raceway surfaces wherein an inner ring on the outer peripheral surface of which is formed with one of double row inner raceway surfaces is fitted into a hub wheel integrally formed with a wheel mounting flange or into another inner ring on the outer peripheral surface of which is formed with the other double row inner raceway surfaces; and a connected portion of them has a plastic deformed connection means having an axial pull-out proof force more than 160 kN.

3. A bearing apparatus for a driving wheel of vehicle of claim 1 wherein the hub wheel, the constant velocity universal joint and the double row rolling bearing are assembled as a unit, the hub wheel and the outer joint member of the constant velocity universal joint are fitted each other; one of the inner raceway surfaces of the double row rolling bearing is formed on the hub wheel and the other of the double row inner raceway surfaces is formed on the outer joint member; a hardened irregular portion is formed on a radially outwardly arranged member at the fitted portion of the hub wheel and the outer joint member; and the hub wheel and the outer joint member are integrally connected via plastic deformation of a radially inwardly arranged member by radially outwardly expanding the radially inwardly arranged member so as to make the hardened irregular portion of the radially outwardly arranged member to bite into the surface of the radially inwardly arranged member.

4. A bearing apparatus for a driving wheel of vehicle of claim 3 wherein the outer joint member of the constant velocity universal joint is fitted into the hub wheel; one of the inner raceway surfaces of the double row rolling bearing is formed on the hub wheel and the other of the double row inner raceway surfaces is formed on the outer joint member.

5. A bearing apparatus for a driving wheel of vehicle of claim 3 wherein the outer joint member of the constant velocity universal joint is fitted onto the hub wheel; one of the inner raceway surfaces of the double row rolling bearing is formed on the hub wheel and the other of the double row inner raceway surfaces is formed on the outer joint member.

6. A bearing apparatus for a driving wheel of vehicle of claim 1 or 2 wherein the hub wheel, the constant velocity universal joint and the double row rolling bearing are assembled as a unit, the hub wheel and the outer joint member of the constant velocity universal joint are detachably connected with being fitted each other; one of the inner raceway surfaces of the double row rolling bearing is formed on the inner ring fitted onto the hub wheel and the other of the double row inner raceway surfaces is formed on the hub wheel; a hardened irregular portion is formed on the inner ring; and the inner ring and the hub wheel are integrally connected via plastic de-

formation of the hub wheel by radially outwardly expanding the hub wheel so as to make the hardened irregular portion of the inner ring bite into the surface of the hub wheel.

7. A bearing apparatus for a driving wheel of vehicle of any one of claims 3 through 6 wherein the portion to be radially outwardly expanded is projected beyond the hardened irregular portion.

8. A bearing apparatus for a driving wheel of vehicle of claim 7 wherein the hardened irregular portion is formed by substantially orthogonally crossed grooves comprising plurality of axial grooves and annular grooves; and the outer diameter of the portion projected beyond the hardened irregular portion is larger than the bottom diameter of the annular grooves or the axial grooves.

9. A bearing apparatus for a driving wheel of vehicle of any one of claims 1 through 8 wherein the load supporting capacity of the bearing of inboard side of the double row rolling bearing is higher than that of the bearing of outboard side.

Fig. 1

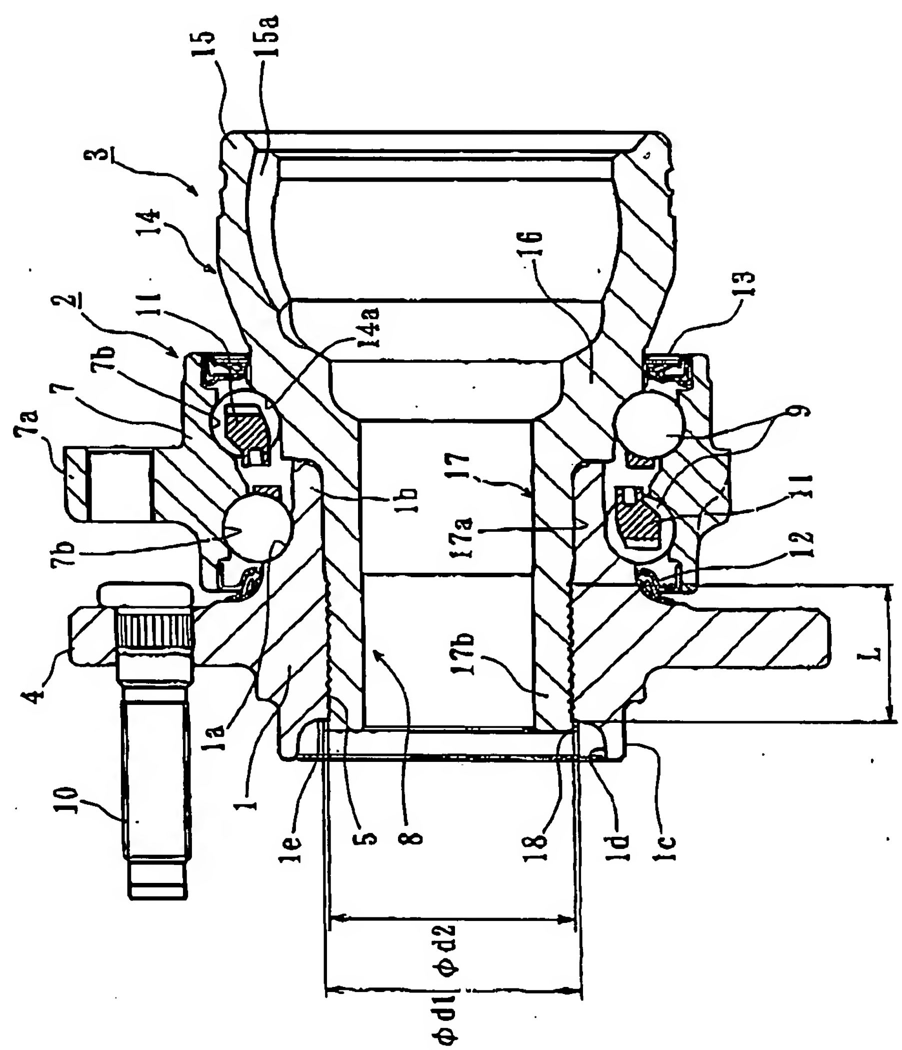
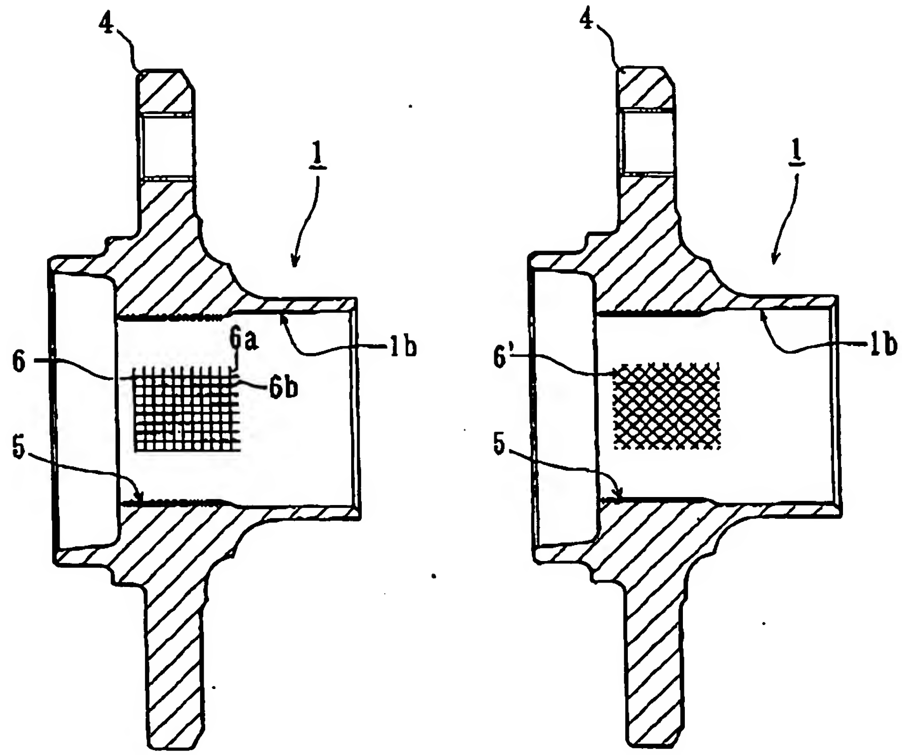
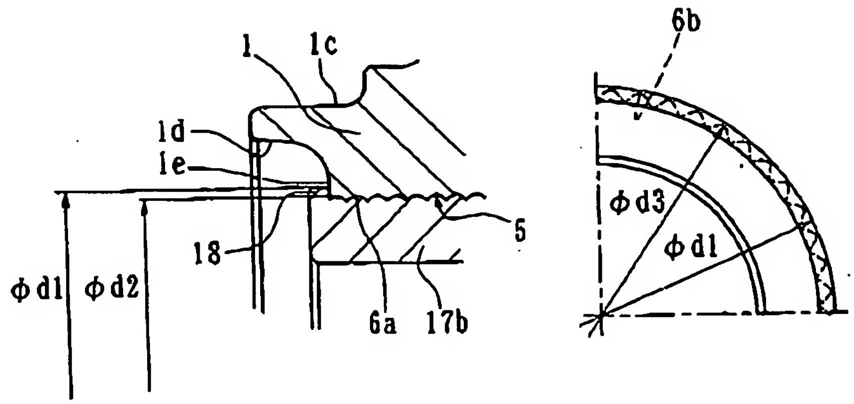


Fig. 2



(a) (b)

Fig. 3


1
1c
1d
1e
18
5
6a
17b
φd1
φd2
6b
φd3
φd1

(a) (b)

Fig. 4

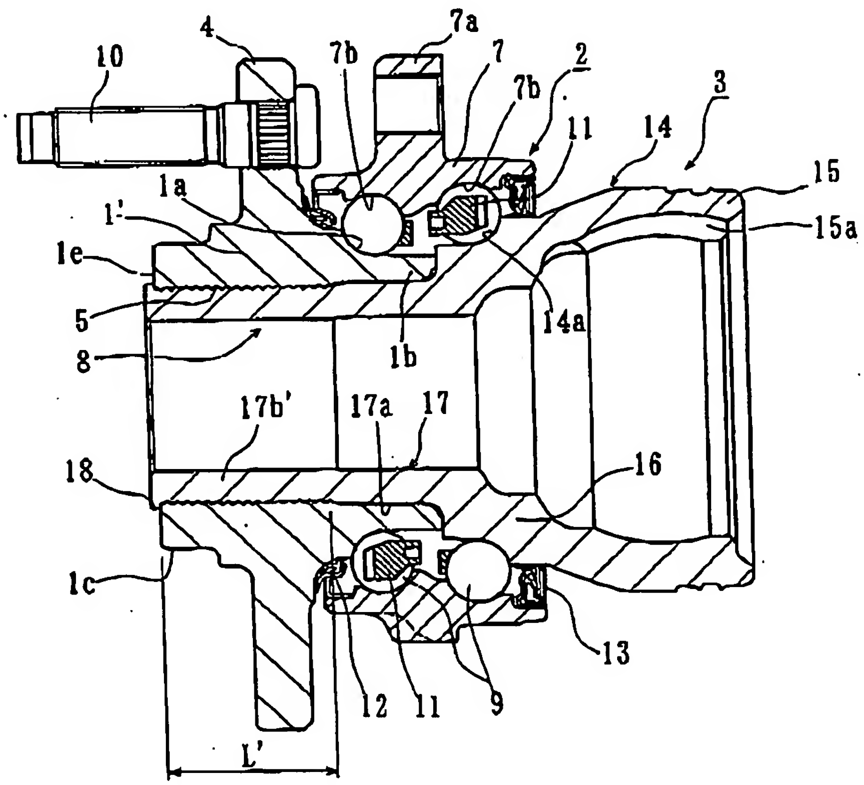

4
10
7a
7b
7
2
7b
3
11
14
15
1a
1'
15a
1e
5
14a
8
1b
17b'
17a
17
18
16
1c
13
12
11
9
L'

Fig. 5

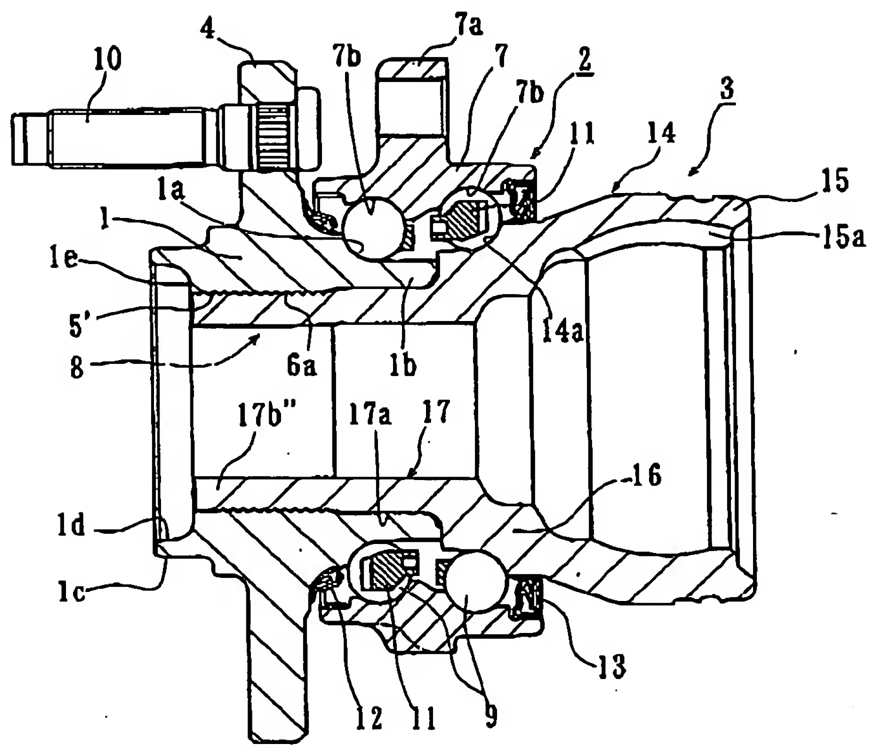

4
7a
10
7b
7
2
7b
3
11
14
1a
15
1
15a
1e
5'
14a
8
6a
1b
17b"
17a
17
16
1d
1c
13
12
11
9

Fig. 6

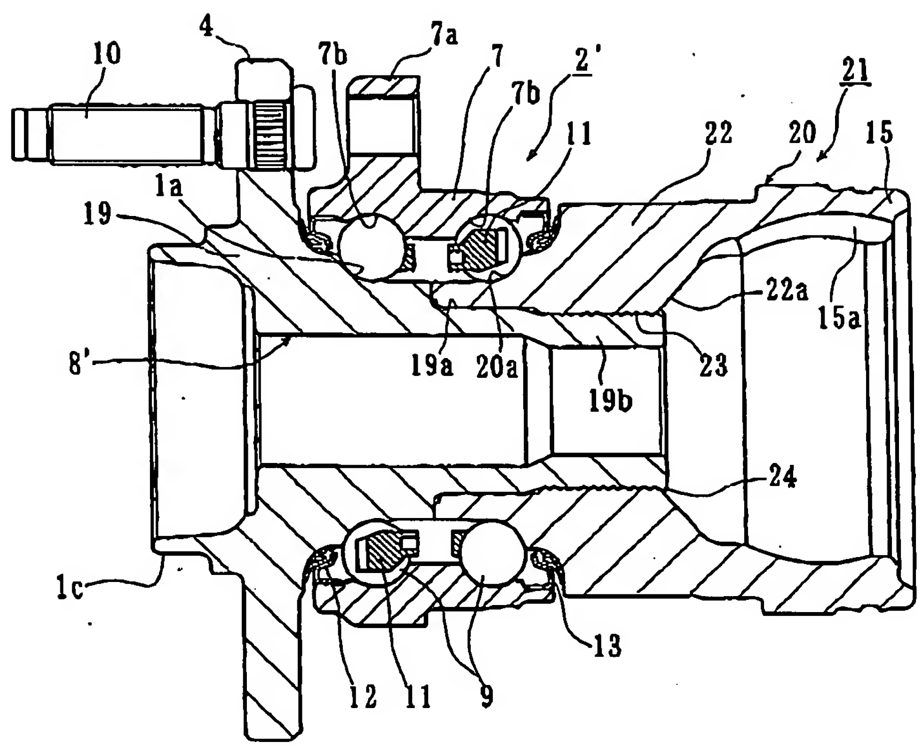
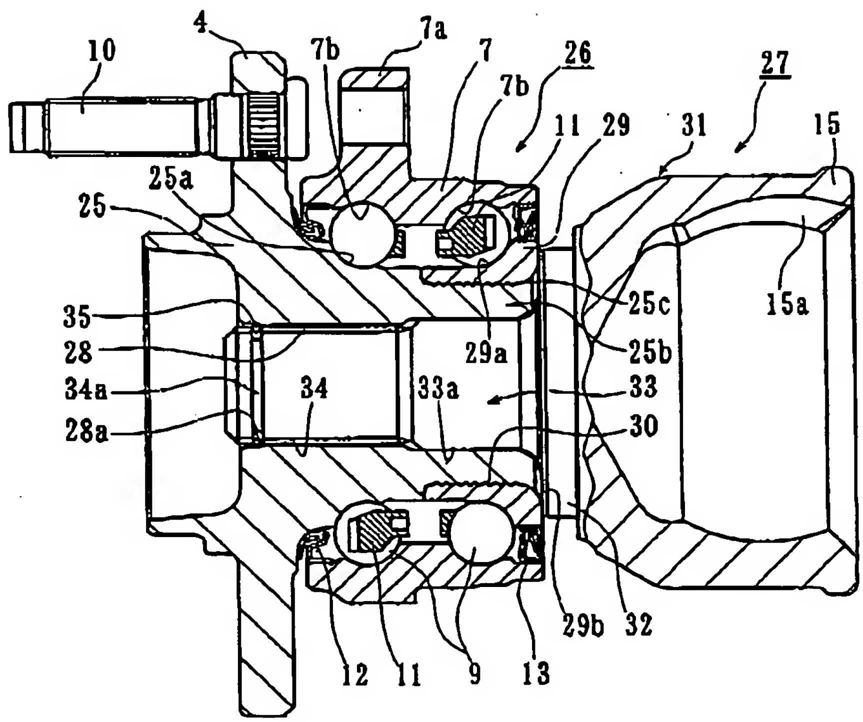

10
4
7a
7b
7
2'
7b
21
11
22
20
15
1a
19
22a
15a
8'
19a
20a
23
19b
24
1c
13
12
11
9

Fig. 7



4
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7b
7a
7
26
7b
11
29
31
27
15
25a
25
35
28
34a
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29a
25c
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15a
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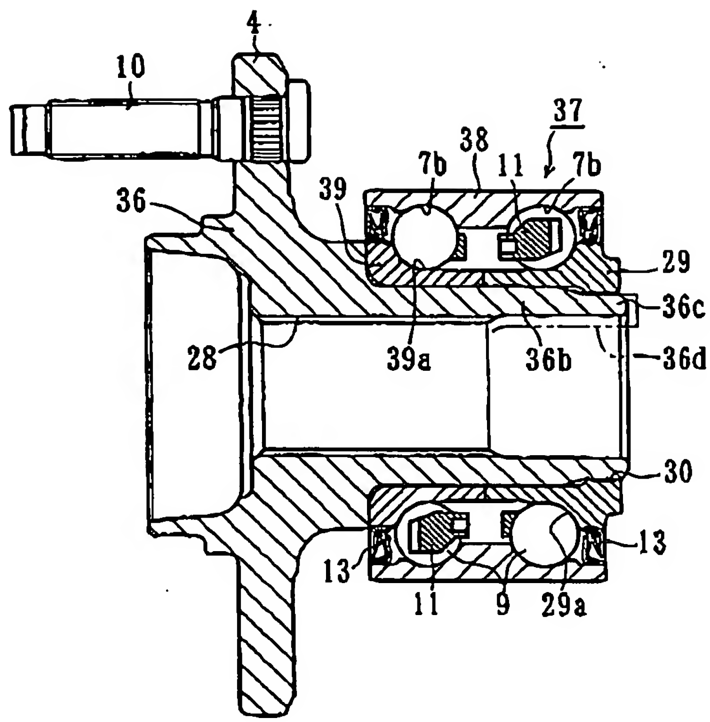
9
13
29b
32

Fig. 8


4
10
37
38
7b
11
7b
39
36
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36d
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13
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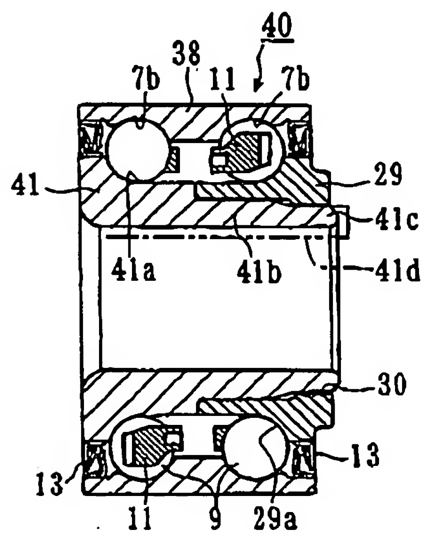
11
9
29a

Fig. 9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7b
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41
29
41c
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41b
41d
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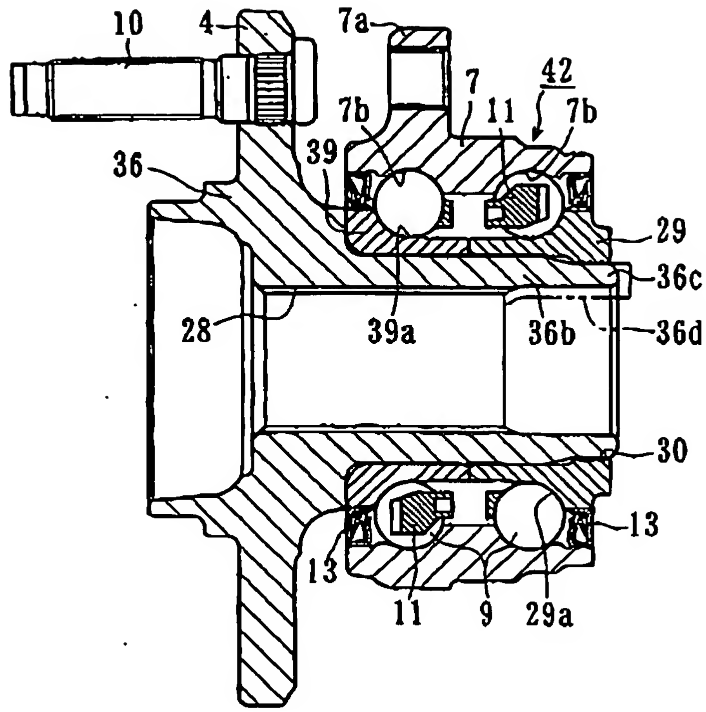
13
11
9
29a

Fig. 10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42
7b
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7b
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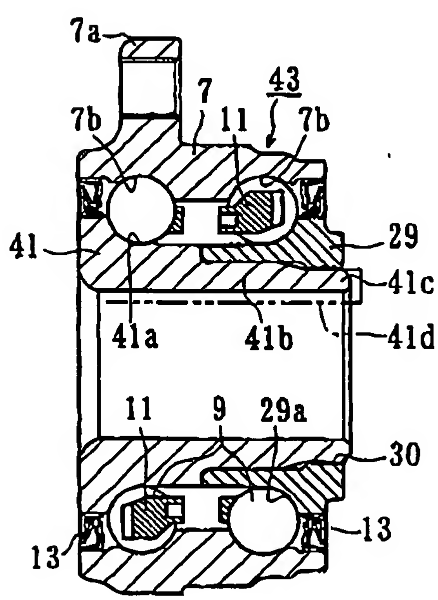
11
9
29a

Fig. 11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7
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7b
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7b
41
29
41c
41a
41b
41d
11
9
29a
30
13
13

Fig. 12

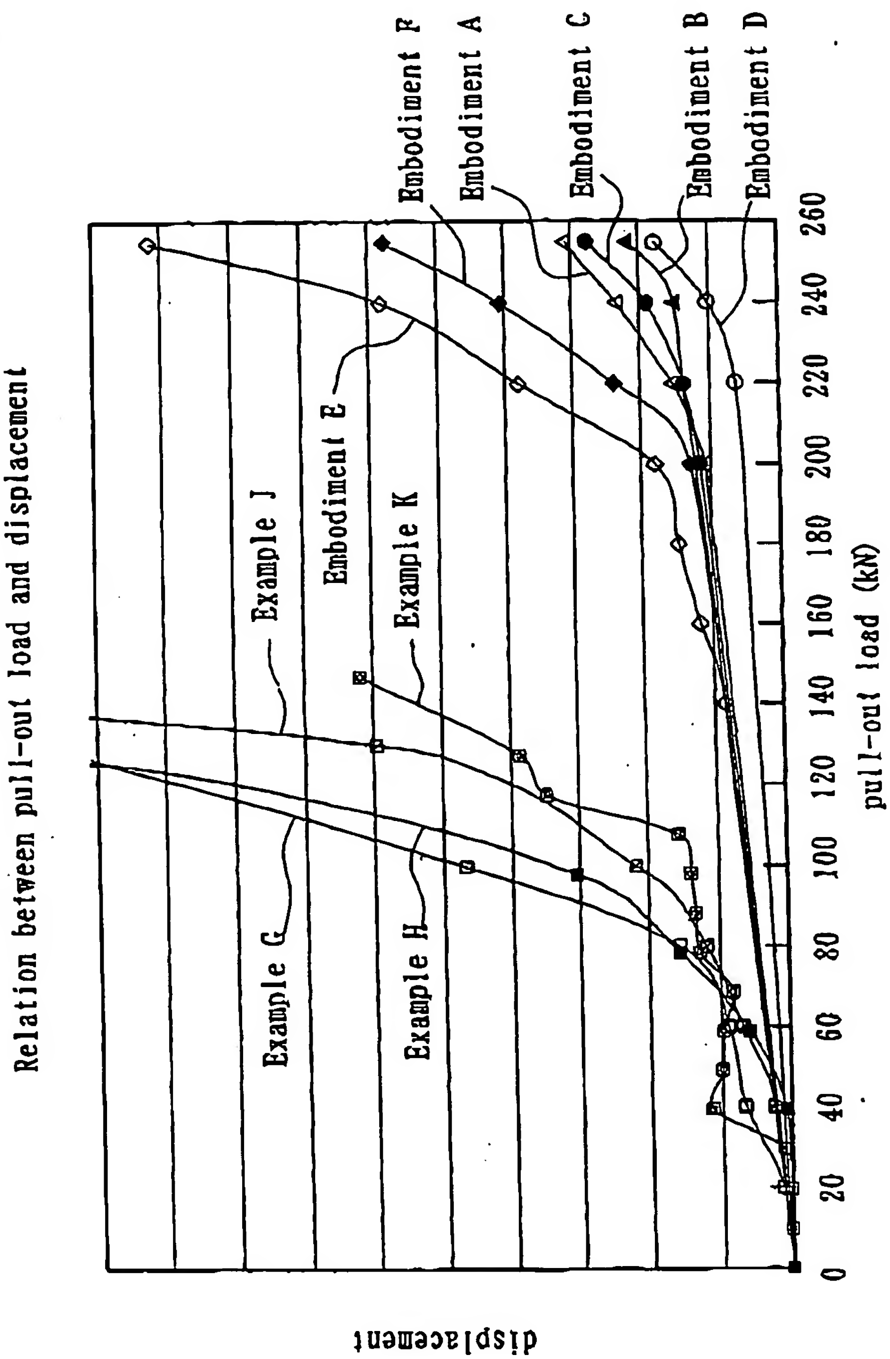
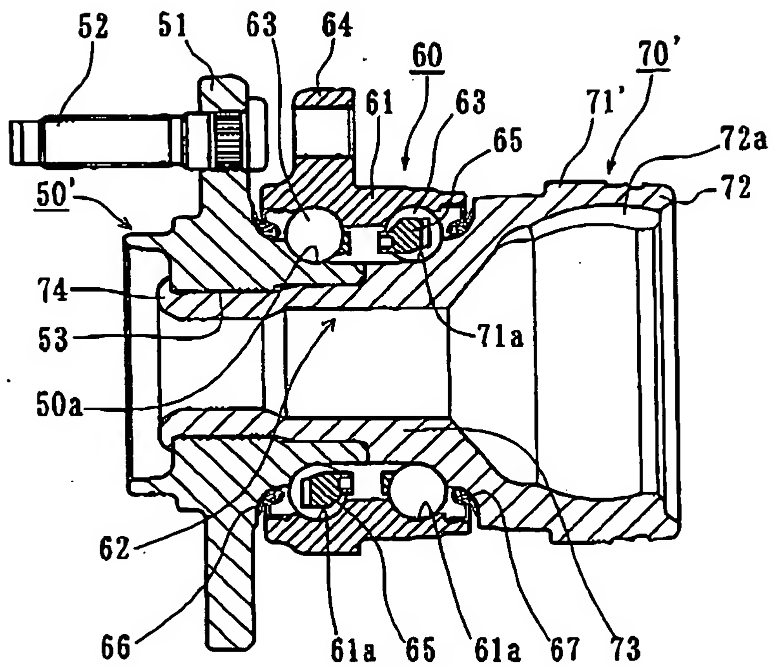

Relation between pull-out load and displacement
Embodiment F
Embodiment A
Embodiment C
Embodiment B
Embodiment D
Embodiment E
Example J
Example K
Example G
Example H
0
20
40
60
80
100
120
140
160
180
200
220
240
260
pull-out load (kN)
displacement

Fig. 13


52
51
63
64
60
70'
61
63
71'
65
72a
72
50'
74
53
71a
50a
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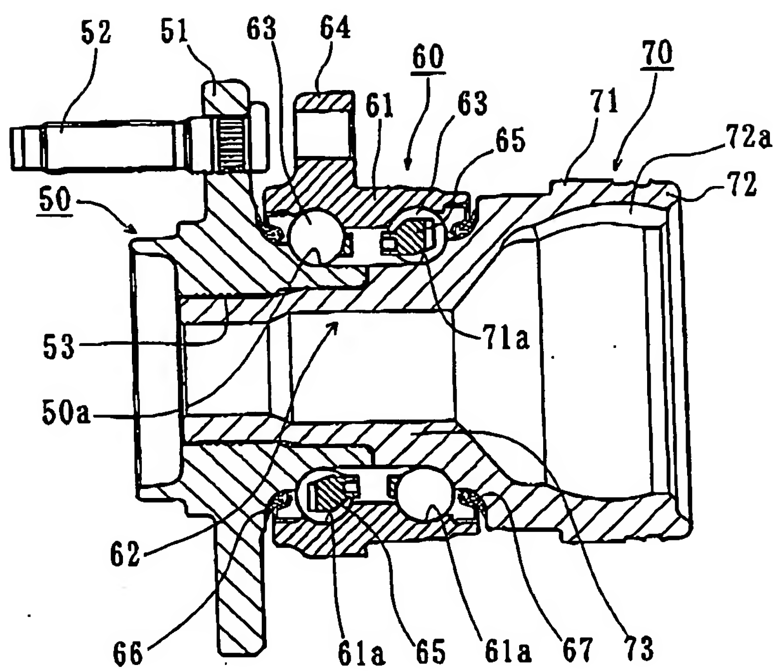
61a
65
61a
67
73

Fig. 14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72a
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61a
67
73